Electronic Services - Los Angeles
M132236X

KEITHLEY

MODEL 413

LOG MICRO-MICRO AMMETER

General Electric Company

GENERAL ELECTRIC
INSTRUMENTATION / COMMUNICATION
1200 KONA DRIVE
COMPTON CA 90220
(213) 642-5017

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof, except tubes, transistors, fuses, and batteries, which, within a year after shipment to the original buyer, proves defective on examination.

DAMAGE IN SHIPMENT

Be sure to include the instrument model number and serial number in all communications.

If the instrument is damaged when received, or fails to operate properly, a claim should be filed with the carrier. Upon receipt of the claim agent's report, we will inform you regarding repair or replacement.

REPAIRS

When returning an instrument for repair or recalibration, it should be securely packed against shipping damage and sent to the factory, freight prepaid. A brief letter describing the difficulty should accompany the instrument.

SECTION I INTRODUCTION

The Keithley Model 413 micro-microammeter is a line operated vacuum tube electrometer with a logarithmic meter scale which covers the range 10^{-5} to 10^{-11} ampere without range switching.

The features include full-scale voltage drop at the input of less than five millivolts, zero drift of less than .05 decade in 24 hours, good accuracy, built-in calibration standards and large output voltage. The output is sufficient to drive the numerous potentiometer-rebalance 50 millivolt recorders. One output terminal is at ground, making it convenient to connect cathode ray oscilloscopes or pen-driving amplifiers, similar to Brush and Sanborn equipment.

The major panel controls are the OPERATE-CALIBRATE switch and the SET 10^{-10} control which establishes a reference point on the logarithmic scale. Minor controls are the RECOVER button, AMPLIFIER BAL adjustment, SET 10^{-6} adjustment, and the ON-OFF switch. The meter dial is illuminated and serves as the pilot light.

SECTION II DESCRIPTION

The current range covered is 10^{-5} to 10^{-11} ampere and is displayed on a six inch panel meter for maximum readability. Accuracy is within plus or minus 0.2 decade and the output voltage is eight millivolts per decade plus or minus 20%. Positive currents can be accepted and the output voltage is in the negative direction.

Standardization of the 413 is accomplished by turning the OPERATE-CALIBRATE switch to the 10^{-10} position and setting the meter at 10^{-10} by means of the SET 10^{-10} control knob. The calibration signal is supplied by means of a mercury battery and a 10^{10} ohm, 2% resistor.

Calibration of the 413 may be checked by advancing the OPERATE-CALIBRATE switch to 10^{-6} ampere after standardization has been accomplished as above. Adjustment may be made if necessary by means of a front panel screw-driver control labeled SET 10^{-6} AMP.

Amplifier balance may be finally checked by then advancing the OPERATE-CALIBRATE switch to AMPLIFIER BAL and checking to see if the meter needle goes to 10^{-11}. If necessary, a front panel control labeled AMPLIFIER BAL may be used to adjust this setting.

In general only the SET 10^{-10} control is routinely used. The other adjustments will require infrequent adjustment.

Input impedance is minimized by negative feedback. The voltage drop across the input terminals will be less than five millivolts for any position across the meter scale provided that the amplifier balance is properly set.

Grid current is less than 5×10^{-14} ampere and will not affect operation of the instrument.

Input switch labeled RECOVER is located at left side of the panel. Its purpose is to short out the feedback diode and allow quick dissipation of spurious charges which sometimes accumulate on the input of a micro-microammeter, or are caused by overloading the input.

Drift. After one hour warm up if the instrument is set on 1×10^{-10} ampere, the reading will not increase to greater than 1.1×10^{-10} ampere nor decrease to less than 9×10^{-11} ampere in the following eight hours of operation.

Output is provided for driving recorders. The amplifier will develop 50 millivolts for full-scale meter deflection. Connection can be made to the OUTPUT connector at the rear of the chassis.

Response Speed of the 413 depends upon the current and also upon the capacitance of the external circuitry. Because of the method of application of the negative feedback, the slowing effects of capacitance from the high input terminal to ground have been greatly reduced, but are still significant. Table I below gives typical response speeds; viz; the time of 90% response to a step function.

TABLE I

RISE TIME - to 90% of final current

Current change amperes	With no significant external capacitance	With 5000 mmf across input
from 10^{-11} to 10^{-10}	less than 2 seconds	less than 4 seconds
from 10^{-10} to 10^{-7}	less than .15 second	less than .5 second

If averaging of statistical fluctuations at low currents is desired, a polystyrene capacitor may be placed across the feedback diode. The exact value will depend upon the response desired for the particular application but usually will be in the range of 5 to 50 micro-microfarads.

Amplifier Noise is principally power frequency, and is .2 millivolts rms max at the output terminals, irrespective of the current range. From the most general point of view, grid current and amplifier zero drift are also background noise; these have already been discussed.

Circuit Description. A logarithmic scale is obtained by negative feedback from output to input with a diode whose emission is limited by negative plate cathode voltages. The diode used is the grid-filament structure of a type 6418 subminiature tube.

The 6418 offers outstanding advantages in this application:

(1) The filament construction affords rapid warmup and low long term drift.

(2) The grid and filament in this tube are extremely small, so that capacity across the diode is minimal. This results in a considerable improvement in response speed over instruments which employ more conventional diodes.

The diode used for feedback is V8, type 6418. The grid is used as diode anode and the filament as the cathode.

R107 is 200 ohm, ten-turn potentiometer in series with R106 which provide a voltage drop of 2.5 volts. The feedback from the output is connected at this point so that variation of R107 will control the potential in series with the output. This potential is necessary to buck out the voltage across the diode in order that the output can be kept at ground potential when the input is at ground potential.

SECTION III OPERATION

Connect the input to the current source and the output to the recorder or external indicator if desired.

Plug the power cord into a 117 volt 60 cps outlet. Note that since a Sola resonant regulating transformer is used, the power frequency as well as the voltage must be of the proper value.

Turn OPERATE-CALIBRATE switch to 10^{-10} ampere.

Turn on power switch.

After about 15 minutes warm-up set meter to 10^{-10} with SET 10^{-10} control.

Check calibration by advancing OPERATE-CALIBRATE switch to 10^{-6} position. Adjust if necessary as discussed in Section II.

Check amplifier balance by advancing OPERATE-CALIBRATE switch to AMPLIFIER BAL. Adjust if necessary.

Recheck at 10^{-10} and readjust if necessary. Instrument is now ready to operate. Recheck occasionally for drift by using 10^{-10} position on OPERATE-CALIBRATE switch and by adjusting with SET 10^{-10} control. The screw driver adjustments should require infrequent attention.

Input, using cabling.

The current source should be connected to the input connector with the high impedance side of the current source associated with central conductor of the connector. The lead-in cable should be polyethylene, polystyrene, or teflon insulated coaxial cable, and the connector should have teflon insulation. During preparation of cable and connectors, it is essential that all high impedance surfaces be kept scrupulously clean to avoid leakage. With graphite coated cable, it is necessary to avoid tracking graphite onto the high impedance surfaces of the cut end of the insulation and the teflon surface of the connector. Movement of the cable during measurement should be avoided since this will cause spurious needle movements, because of capacitance changes and generation of static charges.

RECORDING: The Model 413 is provided with an output connector on the rear of the chassis for recording. The output for full-scale meter deflection is minus 50 millivolts. Cinch-Jones S-202-B is the chassis connector, P-202 CCT is the mating plug. Terminal #1 is ground.

The Speed of Response, or the time constant of an input transducer and micro-microammeter, depends upon the speed of response of the circuitry of the instrument and also upon the capacitance of the current source and its connecting cable. Because of the way the negative feedback is applied in the Model 413, the external input capacitance is not nearly as important as in the older systems using a voltmeter across a shunting resistor or diode, and quite large capacitances can be tolerated without having an impossibly slow response. Thus, a cable run from an ion chamber to the micro-microammeter is permissible.

+216 Volts. A connector has been mounted on the back face of the chassis to provide +216 volts for polarizing an ion chamber. The potential is derived from OB2 regulators and is well filtered. The supply can be short circuited without damaging it. The chassis connector is Amphenol 80-C and 80-M is the mating plug.

SECTION IV MAINTENANCE

The Keithley Model 413 Micro-microammeter has been designed to give long, trouble-free service. High quality components have been used throughout, and the circuits are stabilized by a substantial amount of negative feedback.

DR 11731-C, at the back is the detailed circuit schematic diagram of the Model 413. The circuit operation was discussed in Section II. Description.

Vacuum tubes V1 and V2 are two electrometer tubes and are located in an aluminum can which plugs onto the top of the chassis near the input terminals. These tubes have been selected, matched and labeled; V1 is Keithley part EV5886-5 and V2 is EV5886-6. The difference between the two is that EV5886-6 does not have to have low grid current. It is recommended that the complete input tube assembly, Model 4102 be kept on hand for replacement purposes.

Feedback diode V8 is a standard 6418 tube which is tested for its logarithmic characteristic. In general any 6418 tube will serve satisfactorily in this position.

INSULATION: All insulation for the high impedance conductors is made of teflon, as are the contact insulators on the range switch. This should give satisfactory service in all humidities. Occasionally, the high impedance insulators should be inspected to insure that they are free from dirt and dust, and brushed off if necessary.

CONNECTOR CAP: The cap for the input connector should be kept in place whenever the connector is not being used. In storage and in transport, it keeps the insulation from accumulating dust, dirt and moisture. Before screwing the cap back onto the connector, be certain that it is clean, so the insulation will not be contaminated and so that a low impedance bridging conductor will not be formed between the high impedance contact and the grounded cap.

Reference Voltage Battery BA-1 should be replaced once yearly.

REPLACEABLE PARTS LIST - MODEL 413

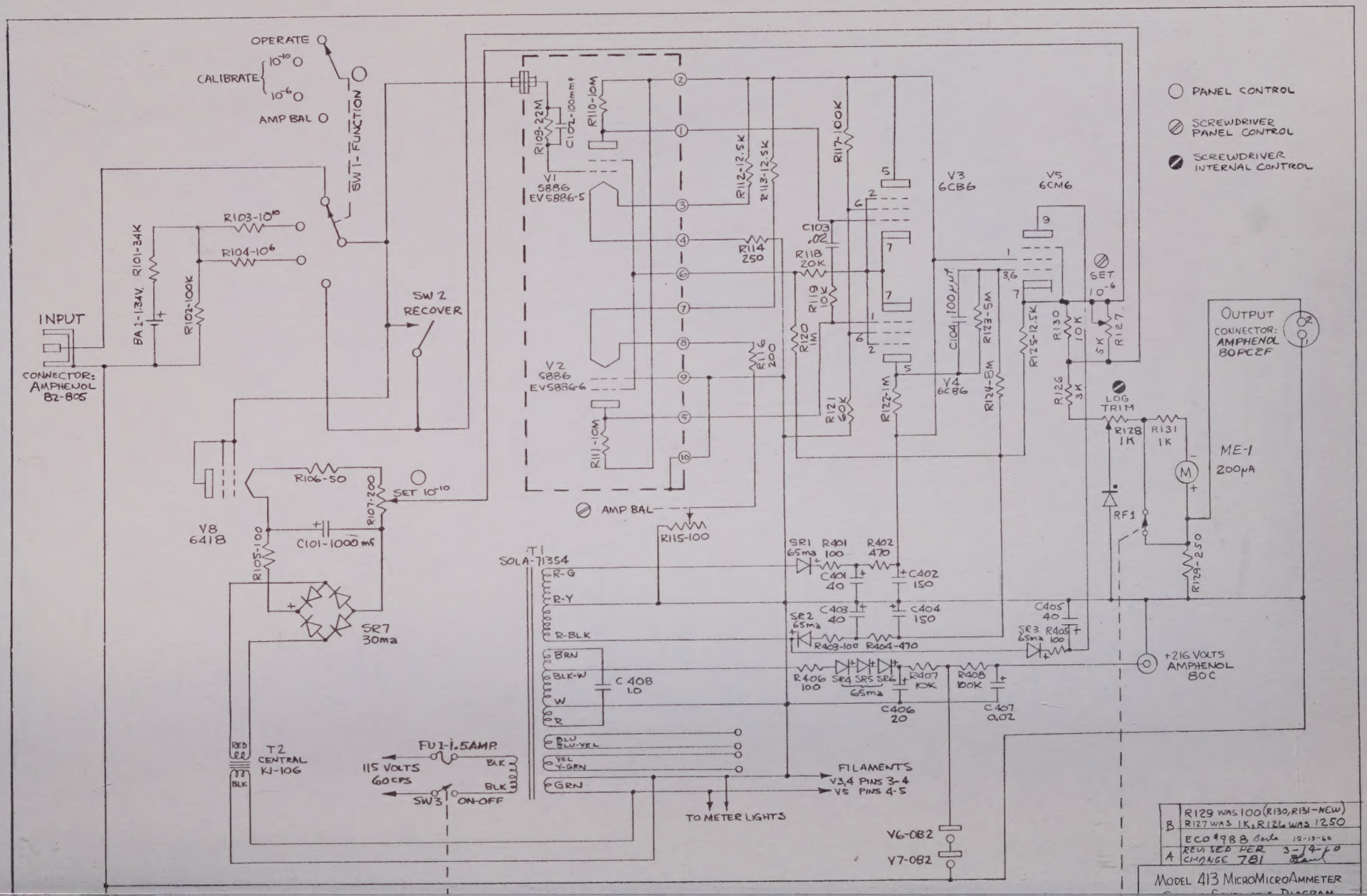
Circuit Desig.	Description	Part No.
BA-1	Battery, 1.34 Volt	BA-8
C-101	1000 mfd. 12 Volt, Electrolytic,Capacitor	C11-1000
C-102	100 mmf, 600 Volt, Disc,Capacitor	C22-100
C-103	.02 mfd. 600 Volt, Disc, Capacitor	C22-.02
C-104	Same as C-102	
C-401	40 mfd. 250 Volt, Electrolytic, Capacitor	C27-40
C-402	150 mfd. 150 Volt, Electrolytic, Capacitor	C9-150
C-403	Same as C-401	
C-404	Same as C-402	
C-405	Same as C-401	
C-406	20 mfd. 450 Volt, Electrolytic, Capacitor	C8-20L
C-407	Same as C-103	
C-408	1.0 mfd. Capacitor Supplied with	TR-17
FU-1	Fuse - 1½ ampere	FU-8
ME-1	Meter, 200 ma. - illuminated	ME-33
R-101	34K Deposited Carbon, 1/3 w. 1% Resistor	R12-34K
R-102	100K Deposited Carbon, 1/3 w. 1% Resistor	R12-100K
R-103	10^{10} Hi-meg, Resistor	R20-10^{10}
R-104	10^{6} Deposited Carbon, 1/3 w. 1%, Resistor	R12-1M
R-105	100 Deposited Carbon, 1/3 w. 1%, Resistor	R12-100
R-106	50 Deposited Carbon, 1/3 w. 1%, Resistor	R12-50
R-107	200 10 - turn, Potentiometer	RP4-200
R-109	22M Composition ½ w. 10%, Resistor	R1-22M
R-110	10M Deposited Carbon 1 w. 1%, Resistor	R13-10M

REPLACEABLE PARTS LIST - MODEL 413

Circuit Desig.	Description	Part No.
R-111	Same as R-110	
R-112	12.5K Wire Wound, 7 w. 3%, Resistor	R7-12.5K
R-113	Same as R-112	
R-114	250 Wire Wound, $\frac{1}{4}$ w. 1%, Resistor	R18-15-250
R-115	100 Linear 2 w. 10%, Potentiometer	RP3-100
R-116	200 Wire Wound $\frac{1}{4}$ w. 1%, Resistor	R18--15-200
R-117	Same as R-102	
R-118	20K Deposited Carbon 1/3 w. 1%, Resistor	R12-20K
R-119	10K Wire Wound 5 w. 3%, Resistor	R4-10K
R-120	Same as R-104	
R-121	60K Deposited Carbon 1/3 w. 1%, Resistor	R12-60K
R-122	Same as R-104	
R-123	5M Deposited Carbon 1 w. 1%, Resistor	R13-5M
R-124	8M Deposited Carbon 1 w. 1% Resistor	R13-8M
R-125	Same as R-112	
R-126	Resistor, Deposited Carbon 1/3 w. 1%, 3 K	R12-3K
R-127	Wire Wound 2 w. 10%, Potentiometer 5 K	RP3-5K
R-128	1K Composition 1 w. 10%, Potentiometer	RP13-1000
R-129	Resistor, Deposited Carbon 1/3 w., 1%, 250	R12-250
R-130	Resistor, Deposited Carbon 1/3 w., 1%, 10K	R12-10K
R-131	Resistor, Deposited Carbon 1/3 w., 1%, 1K	R12-1K
R-401	Resistor, Composition $\frac{1}{2}$ w, 10%, 100	R1-100
R-402	470 Composition $\frac{1}{2}$ w. 10%, Resistor	R1-470
R-403	Same as R-401	
R-404	Same as R-402	
R-405	Same as R-401	
R-406	Same as R-401	

REPLACEABLE PARTS LIST - MODEL 413

Circuit Desig.	Description		Part No.
R-407	10K Composition ½ w. 10%, Resistor		R1-10K
R-408	100K Composition ½ w. 10%, Resistor		R1-100K
RF-1	Rectifier, Diode 26v, 1½ ma		RF-12
SR-1	Rectifier, Selenium 65 ma. 130 Volt		RF-18
SR-2	Same as SR-1		
SR-3	Same as SR-1		
SR-4	Same as SR-1		
SR-5	Same as SR-1		
SR-6	Same as SR-1		
SR-7	Rectifier, Selenium 30 ma.		RF-6
SW-1	Switch, Function		SW-37-1
SW-2	Switch, Recover - Push Button		
SW-3	Switch, Toggle - D.P.D.T.		SW-14
T-1	Transformer, Sola 71354	Regulating	TR-17
T-2	Transformer, Filament		TR-11
V-1	Tube, 5886		EV 5886-5
V-2	Tube, 5886		EV 5886-6
V-3	Tube, 6 CB 6		EV 6CB6
V-4	Same as V-3		
V-5	Tube, 6 CM 6		EV 6CM6
V-6	Tube, Voltage Regulating - CB-2		EV OB 2
V-7	Same as V-6		
V-8	Tube, 6418		EV 6418



B	R129 WAS 100 (R130, R131 – NEW) R127 WAS 1K, R126 WAS 1250
	ECO #988 Boda 12-19-60
A	REVISED PER CHANGE 781 3-14-60

MODEL 413 MICRO MICRO AMMETER

SMEAD–HASTINGS, MINN.
NO. T118BE